# CHAPTER 5

# FLEXIBLE PAVEMENT DESIGN

5-1. Design requirements. Flexible pavement designs will provide the following:

- Sufficient compaction of the subgrade and of each layer during construction to prevent objectionable settlement under traffic.

- Adequate drainage of base course, when frost conditions are a factor, to provide for drainage of base course during spring thaw.

- Adequate thickness above the subgrade and above each layer together with adequate quality of the select material, subbase, and base courses to prevent detrimental shear deformation under traffic and, when frost conditions are a factor, to control or reduce to acceptable limits effects of frost heave or permafrost degradation.

- A stable, weather-resistant, wear-resistant, waterproof, nonslippery pavement.

5-2. Design procedure.

a. General. In designing flexible pavement structure, the design values assigned to the various layers are applied to the curves and criteria presented in this manual. Generally, several designs are possible for a specific site, and the most practicable and economical design is selected. Since the decision on the practicability of a particular design may be largely a matter of judgment, particulars regarding the selection of the final design (including cost estimates) will be included in the design analysis.

b. Design index. The design of flexible pavements for roads, streets, and similar areas will be based on a design index, which is an index representing all traffic expected to use a flexible pavement during its life. It is based on typical magnitudes and compositions of traffic reduced to equivalents in terms of repetitions of an 18,000-pound, single-axle, dual-tire load. Appendix B explains design traffic and equivalency to a basic loading in more detail. The designer is cautioned that in selecting the design index, consideration will be given to traffic which may use the pavement structure during various stages of construction and to other foreseeable uses. For designs involving rubber-tired vehicles, traffic will be classified in three groups, as follows:

Group 1. Passenger cars and panel and pickup trucks
Group 2. Two-axle trucks

Group 3. Three-, four-, and five-axle trucks

Traffic composition will be grouped under the following four categories:

| | |
|---|---|
| Category I. | Traffic essentially free of trucks (99 percent Group 1 plus 1 percent Group 2). |
| Category II. | Traffic including only small trucks (90 percent Group 1 plus 10 percent Group 2). |
| Category III. | Traffic including small trucks and a few heavy trucks (85 percent Group 1 plus 14 percent Group 2 plus 1 percent Group 3). |
| Category IV. | Traffic including heavy trucks (75 percent Group 1 plus 15 percent Group 2 plus 10 percent Group 3). |

Traffic intensities will be as determined for the selection of the proper road or street Class, B, D, and E (See EM 1110-3-130). Where half-track or full-track vehicles or forklift trucks are involved in the traffic composition, the following considerations apply: (a) half-or full-track vehicles or forklift trucks having gross weights of less than 10,000 pounds may be treated as two-axle trucks in determining design index; (b) half- or full-track vehicles weighing less than 25,000 pounds and forklift trucks weighing less than about 15,000 pounds may be treated as three-axle trucks in determining design index; and (c) three additional categories are considered to provide for heavy half- or full-track vehicles and forklift trucks. These are shown in the following tabulation.

| | Vehicle Weight, Pounds | |
|---|---|---|
| Category | Tracked Vehicles | Forklift Trucks |
| V | 50,000 | 30,000 |
| VI | 80,000 | 50,000 |
| VII | 120,000 | --- |

c. Roads and streets. The design traffic to be used in designing a flexible pavement for a road or street for the usual pneumatic-tired road vehicles will be selected from table 5-1.

Table 5-1. Design Traffic

| Class Road or Street | Design Index | | | |
|---|---|---|---|---|
| | Category I | Category II | Category III | Category IV |
| B | 2 | 3 | 4 | 5 |
| D | 1 | 2 | 3 | 4 |
| E | 1 | 1 | 2 | 3 |

Roads and streets sustaining traffic of half- or full-track vehicles heavier than 25,000 pounds will be designed in accordance with design index 6.

d. Parking areas. In the design of parking areas, design-index values for Category I traffic (see table 5-1) will normally be used.

e. Motor pools and motor storage areas. The design of motor pools and motor storage areas will be based on the pertinent category of traffic to be expected in accordance with the criteria delineated in paragraph b. The proper class will be selected based on expected use intensities compared to the road and street class intensities of use delineated in tables 1-1 and 1-2 of EM 1110-3-130. Design-index values will be selected from table 5-1.

(1) General-purpose motor pools and motor storage areas are those accommodating all pneumatic-tired vehicles having gross weights (empty) not exceeding 30,000 pounds and half- or full-track vehicles weighing less than 25,000 pounds. The design will be based on a flexible-pavement design index of 2.

(2) Special-purpose motor pools and motor storage areas are those accommodating pneumatic-tired vehicles of unlimited gross weight and special- or general-purpose engineer and ordnance equipment such as graders, cranes, engineer or ordnance tractors, tanks, etc. Where less than 50,000-pound half- or full-track vehicle loads must be accommodated, the design will be based on a flexible-pavement design index of 4. Bituminous concrete should not be used for motor pool or motor storage areas for pavement for vehicles exceeding 50,000-pound gross weight or where fuel spillage is a problem.

f. Storage areas. Storage areas subject to traffic of forklift trucks will be designed for proper load and traffic intensity in accordance with paragraph 5-2.b. The design index will normally be selected for the pertinent load category for a Class E road or street shown in table 5-1.

5-3. Alternate design procedure. Roads and streets whose design index is less than 4 as determined in paragraph 5-2.b. may be designed by the governing state highway design procedures providing the following conditions exist:

- The traffic composition consists of rubber-tired vehicles only and no repeated use by half-track or full-track vehicles is anticipated.

- Repeated use of fork lift or other special vehicles exceeding 25,000 pounds is not anticipated.

- The resulting design is more economical than a design following the procedures of paragraph 5-2.

- Where frost and/or poor soil conditions exist, the criteria of EM 1110-3-137 and EM 1110-3-138 must be met.

5-4. Compaction criteria. The compaction criteria presented in EM 1110-3-141 are applicable except as modified herein. Data from tests made on flexible pavements that have been subjected to controlled traffic indicate that such traffic induces a significant compaction effort in the layers of the pavement structure. The compaction effort is highest near the surface, decreases with depth, and varies with axle load and repetitions of load. Figure 3-1 shows the compaction requirements to be used in the construction of roads, streets, and open storage areas. The data in figure 3-1 should be used to establish the percentage of compaction to be specified in the construction specifications for the various layers, or the thickness of overlying layers required to prevent densification in a given layer under traffic. Separate requirements are shown for soils with a plasticity index equal to or less than 5 and a liquid limit of 25 or less and those with a plasticity index greater than 5 and a liquid limit greater than 25. Examples of the use of figure 3-1 are given in appendix B.

5-5. Thickness criteria. The thickness criteria given in EM 1110-3-141 will apply except as modified herein. Statements concerning specific design curves for aircraft loading in EM 1110-3-141 are not applicable. Thickness design requirements are given in figure 5-1 in terms of CBR and the design index determined as discussed in paragraph 5-2. For frost condition design, thickness requirements will be determined from EM 1110-3-138. As applicable, reduction in thickness for rainfall and water table depth criteria in EM 1110-3-136 may be used.

a. Equivalency factors. The use of stabilized soil layers within a flexible pavement provides the opportunity to reduce the overall thickness of pavement structure required to support a given load. To design a pavement containing stabilized soil layers requires the application of equivalency factors to a layer or layers of a conventionally designed pavement. To qualify for application of equivalency factors, the stabilized layer must meet appropriate strength and durability requirements set forth in EM 1110-3-137. An equivalency factor represents the number of inches of a conventional base or subbase which can be replaced by 1 inch of stabilized material.

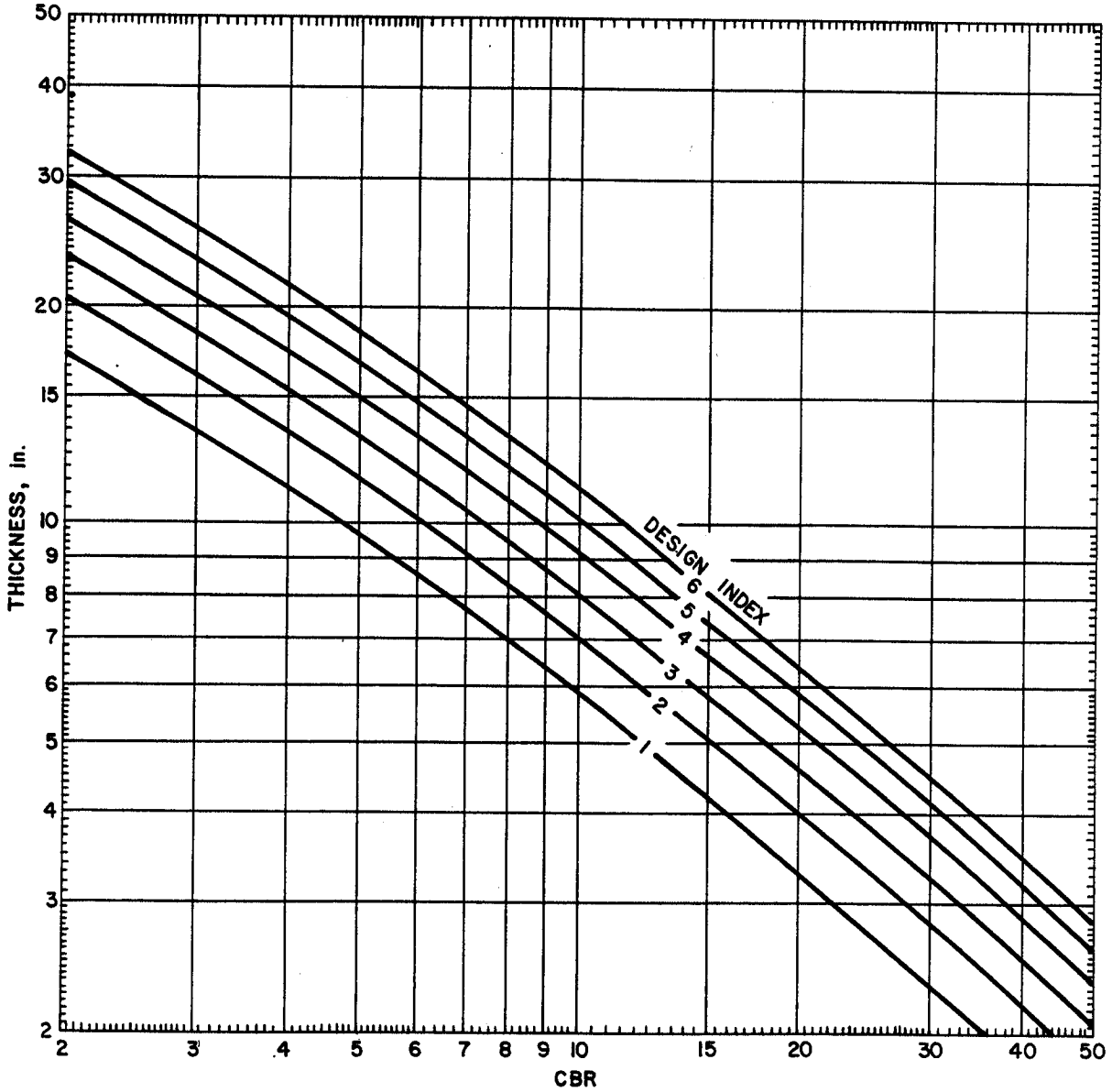


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FIGURE 5-1. THICKNESS DESIGN REQUIREMENTS

Equivalency factors are determined as shown on table 5-2 for bituminous stabilized materials, and from figure 5-2 for materials stabilized with cement, lime, or a combination of fly ash mixed with cement or lime. Selection of an equivalency factor from the tabulation is dependent upon the classification of the soil to be stabilized. Selection of an equivalency factor from figure 5-2 requires that the unconfined compressive strength as determined in accordance with ASTM D 1633 be known.

Table 5-2. Thickness Criteria

| Material | Equivalency Factors | |
|---|---|---|
| | Base | Subbase |
| All-bituminous concrete | 1.15 | 2.30 |
| GW, GP, GM, GC | 1.00 | 2.00 |
| SW, SP, SM, SC | a | 1.50 |

[a]Not used for base course material.

b. Minimum thickness. The minimum thickness requirements for a stabilized base or subbase is 4.0 inches. The minimum thickness requirements for the asphalt pavement are the same as shown for conventional pavements in table 3-1.

5-6. Surface smoothness. Surface smoothness will be specified in terms of maximum permissible deviation from a 10-foot-long straightedge. All surface courses will have a maximum deviation of 1/4 inch. All intermediate courses will have a maximum deviation of 3/8 inch. More restrictive airfield construction tolerances will not be imposed to roads and streets even when both road- and airfield-type pavements are to be constructed under one contract.

5-7. Shoulders and similar areas. These areas are provided only for the purpose of minimizing damage to vehicles using them accidentally or in emergencies; therefore, they are not considered normal vehicular traffic areas. Normally, shoulders will not be paved. Unpaved shoulders will be surfaced with soils selected for their stability in wet weather and will be compacted as required. Dust and erosion control will be in accordance with EM 1110-3-136. Shoulders will not block base-course drainage, particularly where frost conditions are a factor. Where paving of shoulders is deemed necessary, the shoulders will be designed for the expected traffic in accordance with procedures delineated in paragraph 5-2 and appendix B.

5-8. Sidewalk construction. Permanent bituminous sidewalks will consist of a 4-inch-thick base with a 1-inch-thick bituminous surfacing. Material used locally in base construction for roads will

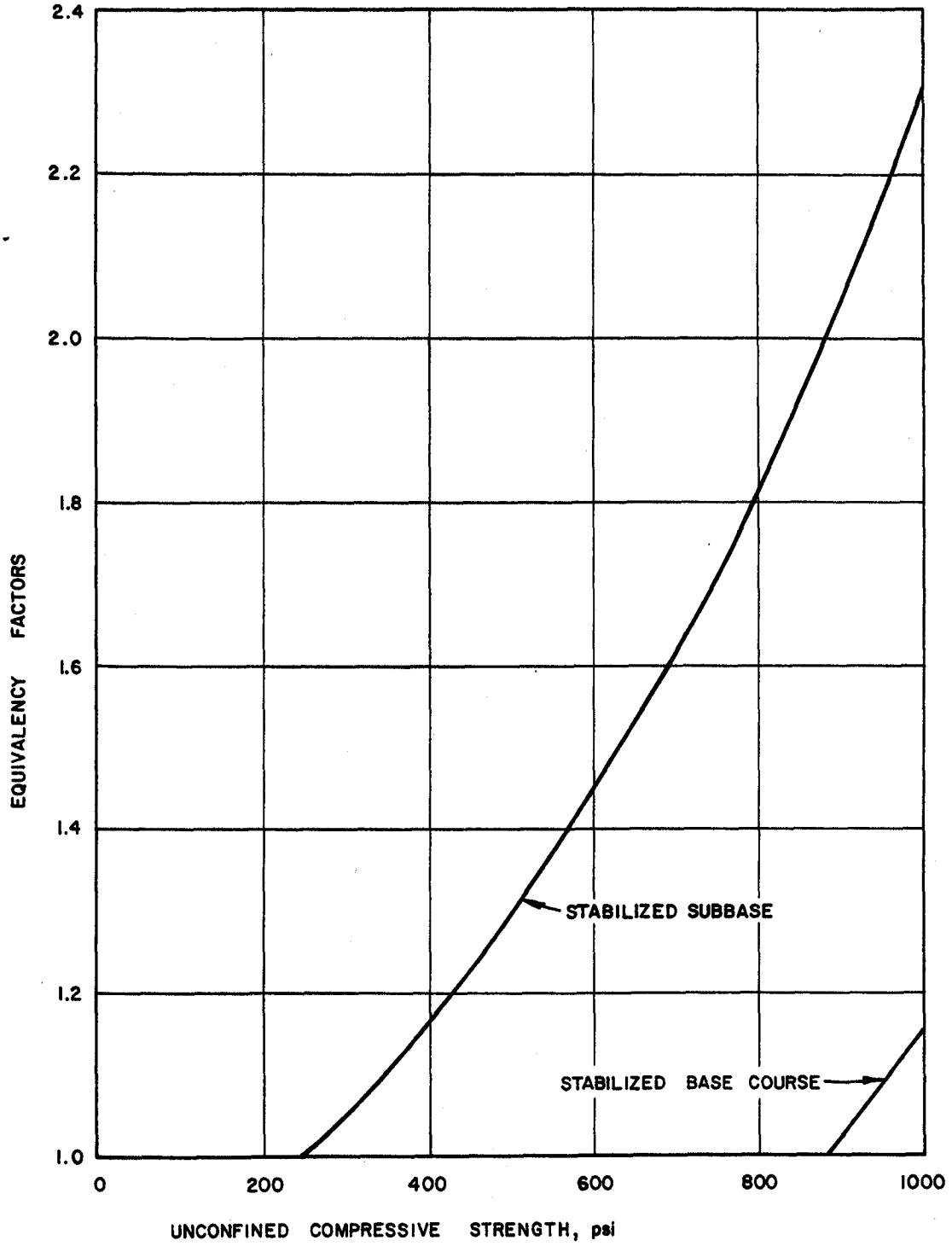


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FIGURE 5-2. EQUIVALENCY FACTORS FOR SOILS STABILIZED WITH CEMENT, LIME, OR CEMENT AND LIME MIXED WITH FLY ASH

normally be suitable as sidewalk base material. Bases may also be constructed of soils stabilized in place with portland cement, lime, bituminous materials, or other acceptable stabilizers. In frost and permafrost areas, bases of sidewalks should be non-frost-susceptible in accordance with EM 1110-3-138, as applicable. The bituminous surfacing may consist of hot- or cold-mix bituminous concrete, sand-asphalt or sand-tar mixes, or sheet asphalt; in locations where the surface texture is not of prime importance, spray surface treatments may be used. Temporary walks or walks that are seldom used will be constructed of stable or stabilized soils or rock screenings containing granular and colloidal materials combined in the proportions necessary to insure maximum density and stability under varied weather conditions, including frost action. Where necessary, the life of these walks may be prolonged by the application of bituminous surface treatments or by the addition of suitable stabilizing agents.

5-9. Special considerations for open storage areas. In general, dense mixture types of asphalt concrete will provide adequate paving to meet special needs. In the design of open storage areas, consideration will be given to any special requirements necessary because of the use of a particular area. In repair yards, for instance, the final-surface texture will be one that will promote quick drying and will not contribute to the easy loss of nuts, bolts, and tiny parts. Such areas may receive a surface treatment of emulsified asphalt combined with selected fillers to provide a smooth resilient surface that is easy to clean and maintain. In areas primarily subjected to static loads, pavement types which require traffic to keep them alive should not be used. Mixtures in such areas will contain approximately 50 percent coarse aggregate. Areas subject to an appreciable amount of foot traffic will be designed to avoid the occurrence of free bituminous material on the surface. Foot traffic areas such as walkways should utilize the highest viscosity rated asphalt possible that is commensurate with the climatic conditions and aggregate properties of the mix.